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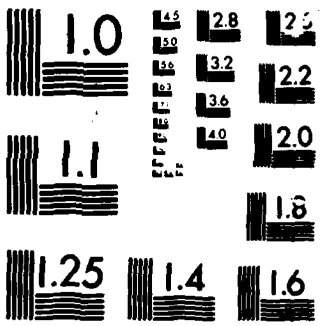

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by

William N. Seelig

Margo Walter

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Ocean Engineering

CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON NAVY YARD
WASHINGTON, DC 20374

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MODEL STUDY OF MOORING FORCES FOR A BARGE MOORED WITH SYNTHETIC LINE

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William N. Seelig
Margo Walter

1. Introduction

Forces on a moored barge are due to the combined action of wind, current and wave forces. Wave induced forces in the mooring lines are produced when the lines attempt to resist barge motions caused by the waves. Physical model studies are especially useful in examining the effect of the waves if the waves are large and/or in shallow water, where the waves are non-linear. This report describes a series of nine tests conducted to determine the maximum mooring line forces for selected conditions.

2. The Problem

Little information is available in the literature for estimating mooring forces due to large waves striking a barge. A preliminary rule-of-thumb used is to take the dynamic load as one-third of the calculated static load. The purpose of this study is to refine the estimates of wave induced force for a specific example by examining the effects of wave height and period on a model barge.

3. The Model Study

A 1 to 100 scale Froude model was selected for this study because the scale was convenient, breaking waves were sufficiently turbulent to minimize Reynold's effects and the model wave periods were long enough to prevent significant surface tension effects.

The model scales were:

horizontal and vertical lengths	1 to 100
time scale	1 to 10
weight and force scales	1 to one-million

The tests were conducted in the One and One-Half Foot wave tank of the U.S. Army Corps of Engineers Coastal Engineering Research Center. Only monochromatic waves were tested, so the wave heights, barge displacements and forces can be taken as the maximum produced by a spectrum of waves. All measurements are given in terms of prototype units for a barge 105 feet wide, 120 feet long and with draft and freeboard of 6 feet.

Figure 1 shows the experimental set-up and gives dimensional units for the tests in prototype measurements. Note that a 120 foot high mast was placed on the barge to represent a large antenna. A water depth of 126 feet was used in the flat portion of the tank and waves were produced with a piston-type wavemaker . The barge was then placed at a point along a 1 on 30 slope to simulate moored water depth of 75 feet at the barge location.

The model barge used in these tests was moored with an elastic line (see Figure 1). An important aspect of this material is the amount that the line stretches for a given force. A mooring that allows the barge to move with each wave will have less mooring line tension than a rigid line. Unfortunately, we could not find a model material that exactly reproduced the prototype line behavior, so a compromise was made. The selected model mooring line has proper stretch in the operating range of 100 kips; at smaller loads the model line did not stretch quite as much as the prototype line; and for loads significantly above 100 kips the model line stretched more than the prototype (see Figure 2). The exact effect of the discrepency between model and prototype is not known, but we expect that the model gives reasonable approximations of

prototype conditions.

4. Test Procedure

The following steps were used during testing:

a. the barge was installed in the tank;

b. a line was extended shoreward at a 23° angle* to the horizontal (see Figure 1);

c. various static forces, F, were applied to this line and the displacement of the barge due to each static force was determined to form a calibration curve (Figure 2);

d. a force, F, was placed in the restraining line to simulate 155 kips of horizontal wind and current force, F_H;

e. the test was run and the maximum displacement of the barge measured; this displacement was used with the information in c. (above) to determine the force in the mooring line (force/displacement curve is shown on Figure 2); and

f. wave heights were determined from calibration data, together with Airy shoaling wave theory.

5. Test Results

Monochromatic waves simulating prototype wave periods of 12, 16 and 20 seconds were tested with wave heights ranging from 23 to 48 feet high. The test results are given in the table at the end of this report including: test conditions, maximum horizontal displacement of the barge from the static point, dynamic force and total force in the mooring line.

Test results show that the dynamic wave force in the mooring line rapidly increases as the incident wave height increases (Figure 3). Wave period, however, has little influence, so a design curve is taken as an upper envelope of the observed data (Figure 3).

*NOTE: Tank geometry limited this angle.

Figure 4 is a photograph of a wave breaking on the barge. This wave has a period of 12 seconds and a height of 48 feet.

The "one-third" rule turns out to work well in this case of the significant wave height for this example. At a design significant wave height of 16 feet the predicted dynamic force is 48 kips, which is approximately one-third of the static force of 155 kips. However, the design maximum wave height (1.8 x 16 = 29 feet) produces a dynamic wave force in the mooring line of 95 kips or 60% of the static load.

6. Summary and Recommendations

Very few small scale model studies of a barge moored with synthetic line in breaking wave conditions have been made. These model studies show one of the advantages of this type mooring; the vessel is allowed to move with the waves so the forces in the mooring lines are less than would be produced in a stiffer mooring.

Larger scale tests with design wave conditions are recommended. These tests should be conducted over a wider range of conditions and characteristics of the moorings incorporated into the model.

CHESAPEAKE DIVISION	PROJECT: Empress II Mooring
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DISCIPLINE	E S R: Contract:
Calcs made by: SEELIG date: 4/25/83	Calculations for: Test Results
Calcs ck'd by: date:	

Table - Test Results

Wave Period (sec)	Wave Length (ft)	Wave Height (ft)	Barge* Disp. (ft)	Wave Force (kips)	Total** Force (kips)
12	525	24	19	50	205
		36	37	99	254
		48	89	239	394
16	740	28	30	81	236
		41	40	108	263
		46	63	171	326
20	950	23	27	73	228
		31	37	101	256
		38	55	148	303

*displacement of barge due to dynamic load

** 155 kips of static load was used in these tests

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Naval Facilities Engineering Command NDW
DISCIPLINE

PROJECT: Empress II
Station:
E S R: **Contract:**

Calcs made by: SEELIG **date:** 4/25/83
Calcs ck'd by: **date:**
Calculations for: Test Set-Up

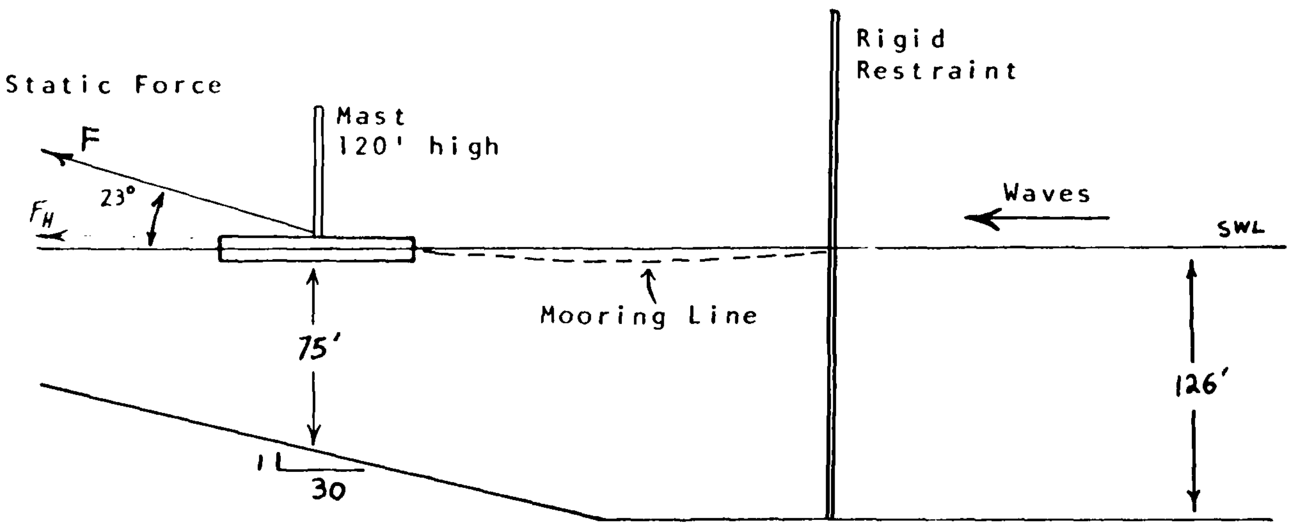

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Figure 1. Test Set-Up

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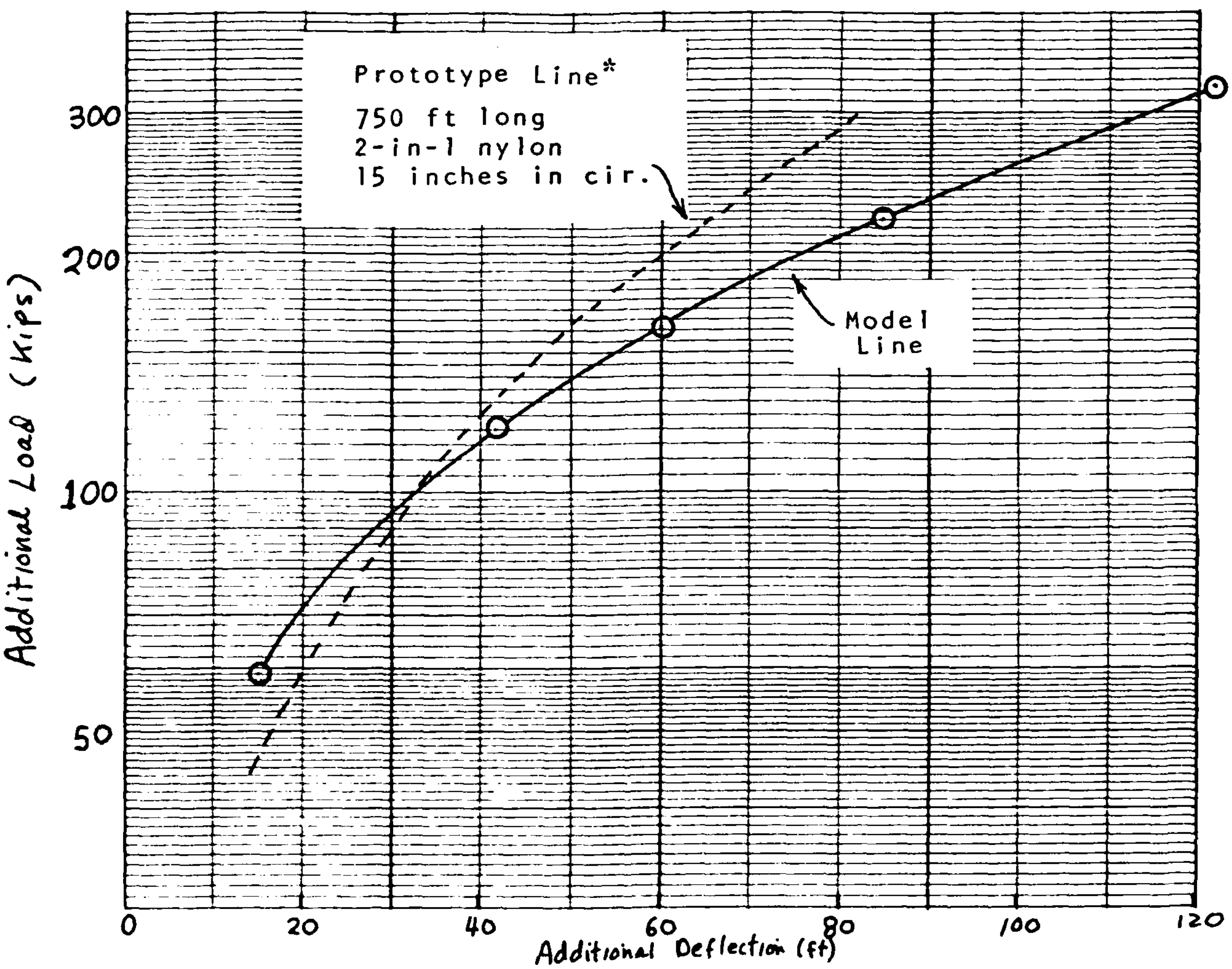

Load Deflection Curves for Additional Loads Above a Static Load of 155 Kips

Figure 2.

*Supplier's data for wet line

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CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	**PROJECT:** Empress II Mooring **Station:** **E S R:** **Contract:**
Calcs made by: SEELIG **date:** 4/25/83 **Calcs ck'd by:** **date:**	**Calculations for:** Model Results

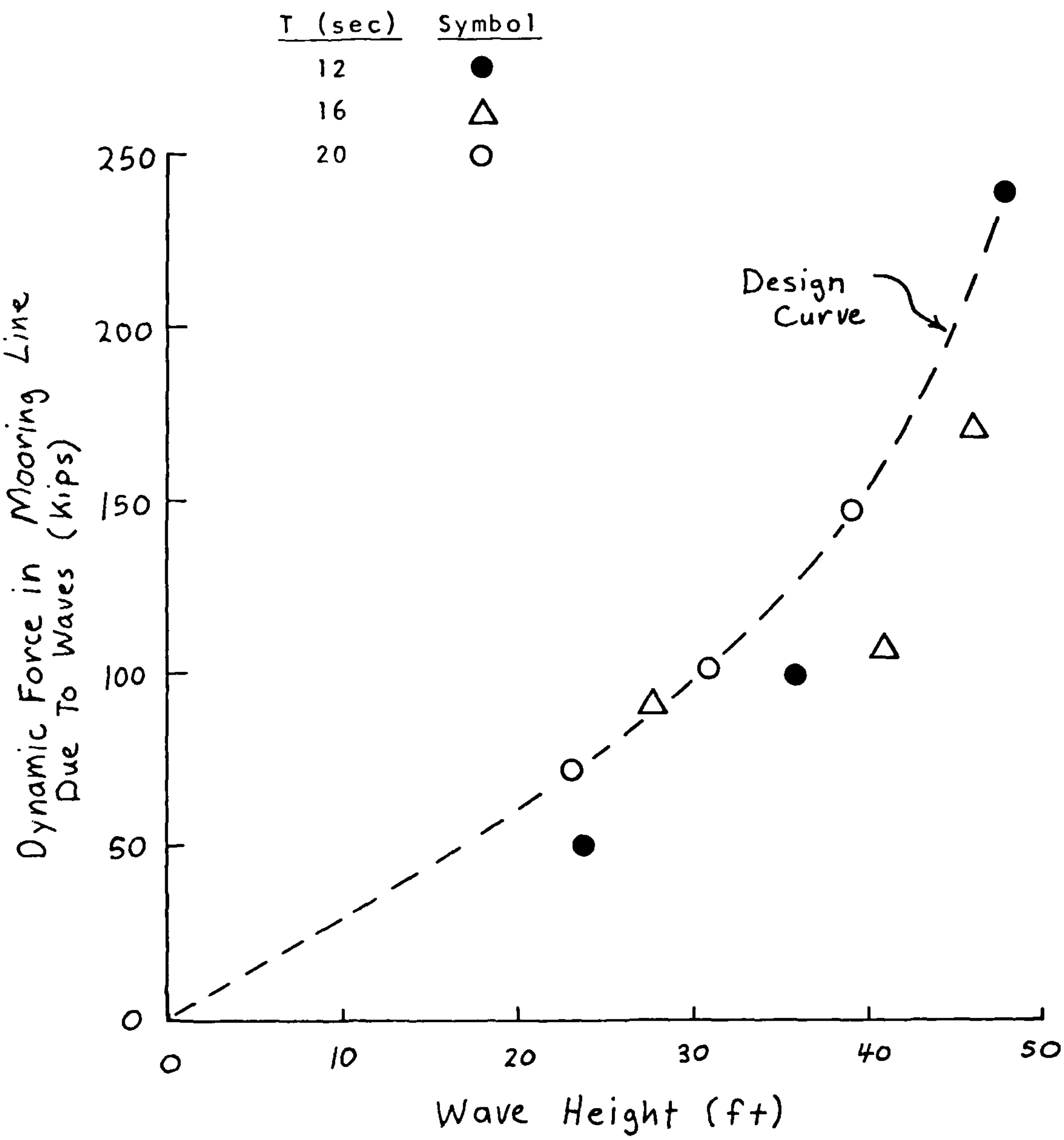

Figure 3. Test Results

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CHESAPEAKE DIVISION	PROJECT: Empress II
Naval Facilities Engineering Command NDW	Station:
DISCIPLINE	E S R: Contract:
Calcs made by: SEELIG date: 5/5/83	Calculations for: Photograph
Calcs ck'd by: date:	

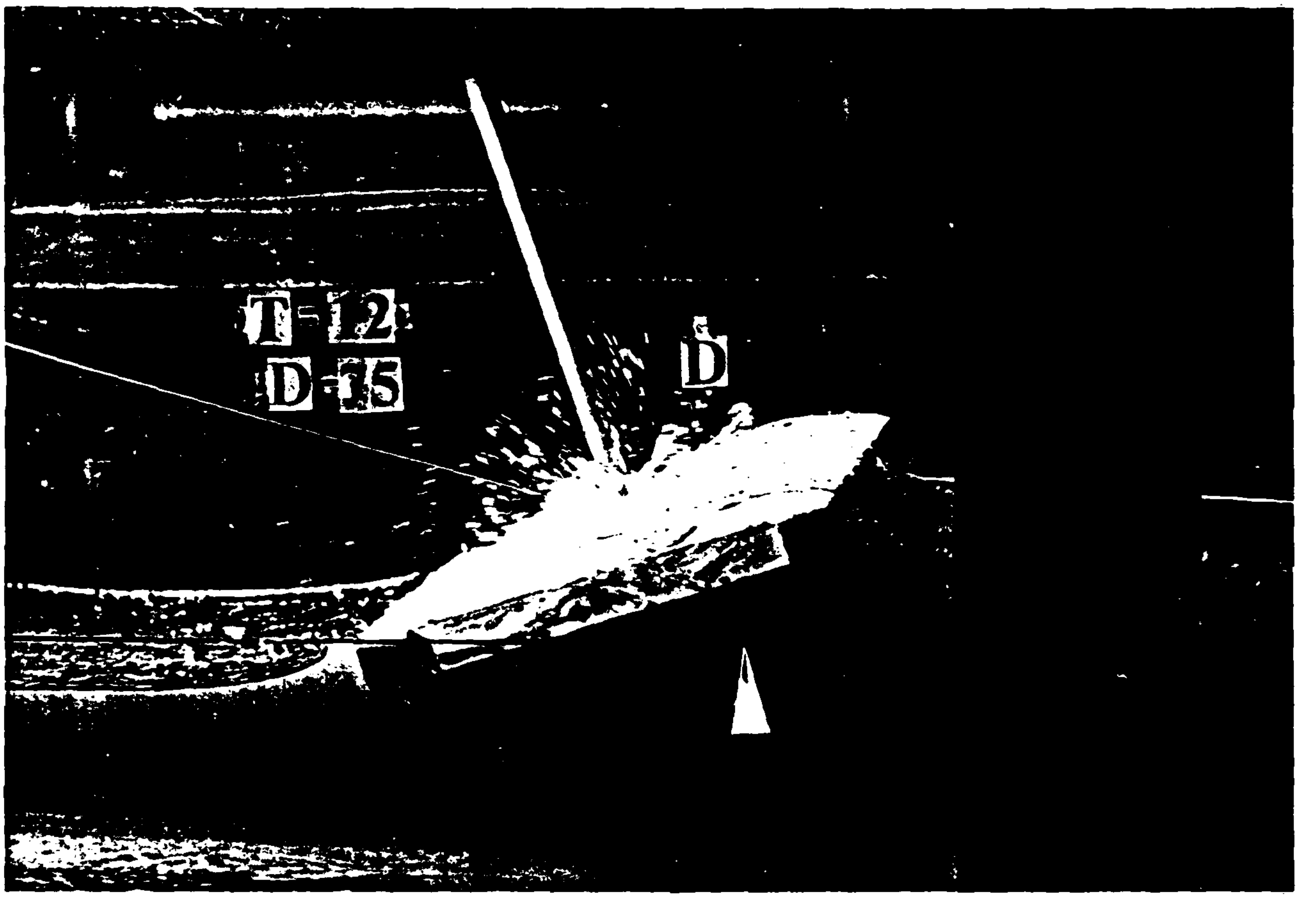

Figure 4. Photograph of a Wave Breaking on the Model Barge

(wave height = 48 feet, wave period = 12 seconds and water depth = 75 feet)

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